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This Semiannual Report covers the period from January 1, 1964, to June 31, 1964, during which research was performed under National Aeronautics and Space Administration Grant NsG-419. Progress in the six principal areas of investigation is briefly reviewed below.

I. K-band Radiometry — Equipment and Observations

A five-channel microwave radiometer capable of operating at frequencies 19.0, 21.0, 22.2, 23.5, 25.5, 29.5, 32.4 Gc/sec has been installed in the 28-ft paraboloid at Lincoln Laboratory, M. I. T. This radiometer is being used for an extensive series of spectral observations of Venus, the earth's atmosphere, the sun, and the moon. The spectral observations of Venus extended through the period of inferior conjunction and are expected to yield information about the planet's atmosphere. These observations will fill an important gap in the previous spectral measurements.

The spectral observations of the earth's atmosphere are being made by observing the brightness temperatures of the sun and the sky as a function of elevation angle. This spectral region encompasses the water vapor resonance at 22 Gc/sec. Six sets of atmospheric observations were accompanied by radiosondes released from M. I. T. in Cambridge, Mass., and from Laurence G. Hanscom Field, Bedford, Mass., near the antenna site. These experiments will yield information about the dependence of the microwave spectrum on the atmospheric temperature and humidity profiles. The sky-brightness temperature has also been measured in a fixed direction for a period of several days. These data are expected to yield information about the nature of the sky-brightness temperature fluctuations reported by observers for other wavelengths.

A special-purpose computer language for the PDP-1 computer has been written to simplify the task of data reduction. This computer program has been used to process data from both the five-channel K-band radiometer, and the MIT/RLE 4-mm radiometer. The observations and data reduction are continuing.

II. Oxygen-Line Observations at High Altitudes

Analysis of the data taken in February 1964, has been completed. The data represent only the first half of the balloon flight because recording was at twice the intended speed. The recovered data were in good agreement with theoretical calculations. Before another pair of flights, in July 1964, changes were made in the radiometer to increase the accuracy and to decrease the minimum detectable temperature difference. Malfunctions of the data-recording equipment limited the usable data to four (of six) channels for one-half of one flight. The quality of these data was excellent, and the radiometer appears to have operated quite well for the duration of the flight. Two more flights are planned for October 1964. A transmitter, as well as the tape recorder, will be on board to allow continuous monitoring and recording of the data on the ground.

III. Radiometers at Millimeter Wavelength

A. 4-mm Radio Telescope

Work on the Research Laboratory of Electronics 4-mm radio telescope and its associated instrumentation has continued. A careful examination of the high side lobe of the receiving pattern (10 db) has shown that it is caused by distortion in the surface of the 10-ft parabola reflector. The gain is down 1-2 db from that expected. It now appears that our present reflector is only very marginally satisfactory for useful observations on large sources (moon and sun) but will be useful on sources whose angular size is small compared with our beamwidth (6 ft), provided that our pointing is sufficiently accurate. A careful evaluation of pointing accuracy by use of an optical telescope with visible stars as references is under way. Initial results indicate the absolute pointing to be well within one beamwidth. Several modifications are under way to improve the digital pointing both in terms of accuracy and convenience of operation.

We had intended to undertake Venus observations during June 1964, but equipment modifications, weather delays, and personnel limitations have made this impossible.

B. 4-mm Radiometer

Four additions to the 4.3-mm radiometric receiver have been made. Base-line drift resulting from interaction between a mismatched ferrite switch and a drifting local oscillator has been reduced by an order of magnitude by inserting a notch filter between the mixer and the switch. A further reduction is anticipated with the addition of a frequency stabilizer. A laboratory thermal-noise standard (150°C ±0.5°C) has been completed and is operational and and stable within ±0.1°C. An automatic noise-figure meter has been completed. It is stable and accurate within 0.1 db and will be used to check the performance of the system periodically and to facilitate tune-up. The present receiver sensitivity is 1.8°K for an integration time of one second.

Preparation for 4.3-mm and 2.15-mm semiconductor work is under way. A moderately clean work area is planned.

A 4.3-mm degenerate parametric amplifier has been shown to be feasible, and a preliminary design is under way. We anticipate at least an order of magnitude improvement in receiver sensitivity once the amplifier work is completed. This area of work will receive major emphasis during the coming year.

IV. Solid-State Local Oscillators

Work is continuing on the theoretical and experimental aspects of millimeter-wave varactor multipliers. The 5.5-22 Gc/sec quadrupler has been operated at 100 mw out with 540 mw of drive power. An X-band, de Loach technique measurement test arrangement has been designed and partially constructed in order to obtain more accurate parameters for both commercial and "in-house" varactors. A doubler from 30 Gc/sec to 60 Gc/sec was constructed by using integrated solid-state microwave techniques; completion and testing of the unit and other work on multipliers has been suspended pending installation of a clean work-area facility.

V. Theoretical Interpretations of Observations

The programs reviewed under Items I and II require extensive theoretical computation to facilitate interpretation of the experimental observations. This problem has been partially solved by developing detailed computer programs to treat thermal emission from the terrestrial atmosphere at wavelengths that are characteristic of molecular oxygen, and through a more general program that is typical of a planet with an atmosphere viewed, in its entirety, with earth-based radio telescopes. This work has been reviewed in more detail in the Interim Reports of NASA Grant NsG-250-62, but, because of the close connection between the experimental and theoretical programs, some of the theoretical work forms a part of the research sponsored by this grant.

VI. Microwave Spectroscopy of the Interstellar Medium

The successful detection of the radio lines of OH in the spectrum of the interstellar medium has led to several observational and theoretical programs. A comparison study of H and OH absorption lines in Cassiopeia A with a frequency resolution as narrow as 1.85 kc/sec has revealed new fine structure in the absorption lines. This study has also enabled a determination of the kinetic temperature and small-scale turbulent velocities of the H and OH in the interstellar clouds that give rise to the absorption. Theoretical studies have been directed toward (a) an evaluation of the OH excitation temperature, (b) the detection possibilities of lines of OH in energy levels other than the ground state and in other isotopic species, and (c) an explanation of the observed line-intensity ratios of OH which are in disagreement with the theoretical values.

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